Rates of Change: Computation and the Geometry of Material Organization in Architecture

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GEOMETRY AND CONTINUITY

Architecture has always been concerned in one way or another with continuity: the continuity, for example, between a conceptual diagram and construction, or the continuity between a particular organization of matter (tectonics) and its appearance (form). Historically, geometry and mathematics have served as the primary medium for the conceptualization of continuity, but not without important contradictions.[1] There are numerous examples of these contradictions in both practice and theory, but they are more or less consistent with Vitruvius's account of temple design where he prescribes (unintentionally) two mutually exclusive uses of geometry. On the one hand, he prescribes an ideal Platonic geometry for the design and form of the temple, and, on the other, he prescribes an instrumental geometry to resolve the problems of appearance in the final construction. The reason is that once a temple is built, geometry's effects have a tendency to drift and certain interventions become necessary, such as *entasis*, that is, the application of a curve to orthogonal elements in order to provide consistency between idea and appearance, concept and performance, law and event, truth and sense. The ideal geometry provides continuity between a general set of laws and a general set of design techniques. The instrumental geometry provides continuity between the constructed building and its perceived effects. Despite the fact that we call both techniques geometrical, the meaning of "geometry" is no longer reducible to a monolithic paradigm of ideal relations, proportions, and concepts. For, in fact, it has come into conflict with the specificity of material effects.

Today the problem is not much different. Foreign Office Architect's Yokohama Port Terminal was initially conceived as a topological diagram, a system of folded elements that provided continuity between landscape, infrastructure, and architecture on the one hand, and, on the other, continuity across program, circulation, space, and envelope. The original engineering diagram for the project described the structure through topologically unified geometrical folds which embedded the structure in the building's infrastructural/architectural envelope. Now, it was originally thought that fine-grained sectional cuts through the overall assembly would provide adequate geometrical information from which to derive a continuous structural system of stability. This approach, however, never actually worked. It was a form of reverse engineering in which it was thought that, given enough sectional cuts one could then materially loft those sections. As the final engineering documents indicated, what the project ultimately required was *a second system of geometry*, a geometry of standard radii (of which there were seven sizes) in order to provide maximum stability diagonally, horizontally, vertically, and axially, and, therefore, achieve the desired spatial, programmatic, and circulatory continuity as originally expressed in the competition models and diagrams. The difference is that in the case of FOA, as opposed to Vitruvius, the geometrical problem was resolved through the syntheses of local and global geometries. Whereas Vitruvius privileged an ideal geometry that was homogeneous through and through, FOA emphasized geometries that were instrumental, that were general and particular, homogeneous and heterogeneous. The emphasis on continuity in the architectural effects as a strategy for the continuity of material organization (the constant folding, for example, of architecture, landscape, and infrastructure) was achieved through the sacrifice of continuity in geometrical ideality – or, almost.

SURFACE AND DIGITAL DESIGN

For, in fact, it is important to recognize that FOA's diagram of surface continuity was conceivable only within a paradigm shift in architectural media and techniques. I am speaking of course of the fact that the competition designs by FOA as well other finalists were visually, diagrammatically, and conceptually embedded in an emerging media of surface geometry made possible by the introduction of Alias and eventually Maya and other modeling software that began to make their way into advanced architectural design institutions in the early to mid-nineties. It doesn't matter that these architects also had material models. The fact is that the emphasis on folded surfaces was made possible in the first place by the introduction of product design modeling software into the discipline of architectural education and, at the same time, a theoretical phase-change from Deconstructionist to Deleuzian philosophy: that is from critical theory to materialist philosophy, of which one of the most important organizing concepts became Deleuze's concept of the fold.

Today, these transformations and emphases have become synonymous with what is called digital design in architecture. And, despite the protestations of one of its original contributors, Greg Lynn, digital design has become synonymous with a pictorial logic that privileges form that is yet another form of Ideality.

The question is: what are some of the possibilities in digital media that might allow for a geometry that is intensively material and not over-burdened by a pictorial logic? And the answer, I believe, is to be found, on the one hand, in the use of scientific software for the complex mathematical handling of pattern and, on the other, the rigorous transformation of those patterns through material assemblages.

COMPUTATIONAL DESIGN

If one scans the current academic field, one begins to find pockets of alternative research that challenge the intensive surface logic of digital design. Loosely we could call those strategies "computational" rather than digital, for they privilege neither geometrical paradigms, nor the virtual (which many mistakenly claim is the same as the immaterial), nor the purely material – what they privilege is the synthesis between local and global properties of geometry through the generation of pattern. Among the examples, one could identify the work of Karl Chu, Jesse Reiser and Nanako Umemoto, and Cecil Balmond. Computational design is focused primarily on the possibility of emergent rather than constructed geometry. Its specific value in architecture lies in its ability to establish or generate a meshwork of connections with other disciplines and phenomena for which digital design can only act, as it were, as a visual host. Digital design, I want to say, is primarily representational, whereas computational design is inherently generative and transformative. The most important problem for architecture today is still this: the difference between a representational logic and a material one; between a conceptual and compositional strategy on the one hand, and an interrogative one on the other: between conceptual intentions and a technique: between a form and a form of life.

CFD, GEOMETRY, AND MATTER

Another form of computational design can be found in the development of Computational Fluid Dynamics (CFD). CFD is essentially concerned with the geometry of material relations. Unlike surface-intensive modeling, CFD offers nothing that could be described as bounded form. Whereas surface modeling depends first on the figural ideality of the line or edge as the limit of a plane or the extent of bounded form, CFD is, in fact borderless. For what CFD describes is in fact not a form, but rather evolving shifts in material identities and relations. To this extent it is a tool for the investigation of geometry and topology, not through form, but rather pattern, and, in particular, pattern under conditions of turbulence.

One of the typical concerns of non-linear science in far-from equilibrium systems is the notion of phase change. Phase-change is the expression of what might be called a regime change of organization and behavior emerging out of an identical set of material elements due to an internally or externally derived excess of a particular parameter, such as temperature or pressure. A similar concept occurs in the characterization of fluid flow: turbulence is not a shift in the chemical property of a material but rather a shift its geometrical organization. The difference is that in the latter case, change is characterized by dimensionless numbers (which are, nevertheless empirical), such as the Reynold's number or the Rayleigh number. The mapping of these behaviors therefore lies within the space of mathematical functions and thus patterns rather than discrete numerical objects. And this is where CFD provides an alternative to traditional concepts of geometric and surface-intensive form. CFD exploits two major problems for the description of flow. On the one hand, it provides the definition of edges in terms of orientation, velocity, density, and viscosity rather than form. On the other, it accommodates conditions of transformation (turbulence) where the geometry of material relations exceeds the capacity for gestalt definition, that is, pure pattern. It confronts, in other words, the conflict between form as bounded object and pattern as infinite relation.

One might say that the dilemma of advanced architectural thinking since the 19th century has been caught up in the debate between form and pattern. Indeed, the work of most advanced architecture can be summarized as a conflict between the ideality of static form and the material tendency toward entropic decay or catastrophe where the material and geometrical edge of architecture begins to function according to the logic of matter and events rather than form, function, that is, as the nexus of transformation from, say, ground to envelope, a problem perhaps originally introduced in the architectural and infrastructural designs by Otto Wagner in Vienna, and which calls to mind Taffuri's "Centrality and Surface": the interplay between stasis and flux, the ontological and representational problem of the limit, and the problem of "form as the imposition of limits . . . linked with that of life as a continual betrayal of form itself."[2]

Fluid dynamics is essentially concerned with mapping those transformations and identifying their emergent patterns in terms of particle to particle and particle to system relations. CFD applies the algorithm of those relations to virtual fluid operations by giving them the characteristics available to any particular fluid. It is thus an important tool (medium) from which to derive variegated geometry (local and global) from systems of material homogeneity. However – and here is where CFD differs from other types of mathematical descriptions – fluid flow requires an analysis of change and rates of change and it was not until the advent of calculus that such phenomena could be characterized mathematically. Calculus is actually a means of handling *patterns* of numbers rather than discrete numerical objects. By applying the concept of function to the mathematical domain, analysis was born, and with it a range of tools by which to identify and characterize changes in material systems and complex material organization, over time. As such, the invention of the calculus brought with it a new ontology, an ordering of the world by which to describe material systems in a constant state of flux.

Architecture is undergoing a similar re-orientation. From the engineering of Cecil Balmond and the urban analyses of Rem Koolhaas to the Lindemeyer algorithms of Karl Chu architecture is more and more becoming engaged in finer-grained forms of affiliation and much less affiliations of form – the word in common usage is, once again, pattern. In fluid dynamics, the use of streamlines to describe or diagram the pattern of flow is consistent with the character of flow if that flow is laminar. However, once the system takes on the properties of turbulence, the line is no longer a characteristic property of the material system unless it is used to denote the specific pattern of behavior at that precise instant. (To the extent that time unfolds, it is impossible to fix the complex geometry of material relations according to the logic of the grid, for the grid itself, the grammar of its rectalinearity, the domain of its infinite repetition is, in fact, timeless. CFD, in other words, is a computational mechanism by which we can introduce the issue of time into spatial continuity without pre-figuring the ideality of form).

Much like architecture, fluid dynamics is concerned with the relation between discreet elements and the behavior of the over all system. The relation can be conceived directly on the level of pattern as a self-generating mechanism and the language in which that continuity is embedded is mathematics. The exchange then, between fluid dynamics, mathematics, and architecture is one in which CFD becomes a medium, a calculus, a technique through which to rethink architecture's categories, the relation between them, and their ontological status. It allows architecture to rethink its specificity in light of a growing demand for continuity. At the same time, it is historically linked to that which gave rise to surface-intensive architecture and folding in the first place, that is, the emergence in the 19th century of the Modern episteme and the introduction of analytical techniques as that which replaced Idea, mimesis, Nature, and Style as the conceptual matrix of technique.

Architecture is a means of categorizing certain sets of relations in certain ways, and what ultimately comes into question is the *system*by which a certain set distinctions are drawn. We find of course one of the first modern expressions of this in the classifications proposed by Baron von Cuvier who founded biological identities according to their intricate topology of functions rather than resemblances. This logic had a tremendous influence on various 19th century thinkers including E.E. Viollet-le-Duc, who argued for an architecture based on emerging materials, processes, and organic systems rather than representational paradigms.[3] It had an equally profound influence on Gottfried Semper who re-arranged the historical and genetic categories of architecture and design based on materials and techniques rather than form as such, and which he ultimately expressed in terms of functional relations: Y (or style) $= F\ (x,y,z\ .\ .\ .)$.[4]

The emerging debates about architecture are going to be debates about continuity – not only about its means, but also about the media through which it acquires a sense of material organization and the geometry by which to handle it (the continuity between, for example, types of computation) – but also, debates about the relation between the general and the specific, between the whole and the detail. And thus what is different, and what is emergent is the way in which architecture has begun to handle the relation between the general and the specific as a new kind of problem of continuity, not the continuity of form, but rather the continuity of matter, events and rates of change.

NOTES

[1] Continuity presents a number of problems for architects, but two of the most common are those of design and those of the building as a material organization.

[2] Manfredo Tafuri, "Am Steinhoff, Centrality and Surface in Otto Wagner's Architecture," *Lotus*, 29, 1981: 73-91.

[3] See E.E. Viollet le Duc, *Lectures on Architecture*, vol.2, trans. Benjamin Bucknall, New York, 1987; 58: "we no longer have concrete homogenous masses, but rather a kind of organism . . . ").

[4] See Gottfried Semper, *Manuscript 122* and *124*, *RES* (Fall 1982); 8-22. Of course, when Foucault turned these analytical paradigms back into a reflection on 19th century architecture in the example of the Panopticon, he too was bound to see it not as a formal representation of an ideology or style, but rather as the "function of a function." See *Discipline and Punish*, Vintage Books, New York, 1979; 195-230.